62-4-6

COATING and CHEMICAL LABORATORY

COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS
FIRST REPORT

Report No. CCL # 125

OMS Code No. 5010.11.8000.01

D. A. Project No. BR 593-21-061

Author Charles B. Jordan

Date 21 June 1962

ABERDEEN PROVING GROUND
MARYLAND

This information is furnished for information purposes only with the understanding that it will not be released to any other nation without specific approval of the United States of America-Department of the Army, and that it will not be used for other than Military purposes. It is understood that the furnishing of the attached plans, specifications, technical data, and other information to the recipient does not in any way constitute a license to make, use, or sell the subject matter of any inventions which may be embodied or described in the information so furnished, and any manufacture, use or sale which the recipient makes of any such inventions disclosed therein is at the risk of the recipient.

TABLE OF CONTENTS

UNCLASSIFIED

Report No. CCL # 125

Copy Number

COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS - FIRST REPORT

By

Charles B. Jordan

21 June 1962

OMS Code No. 5010.11.8000.01

Dept. of the Army Project No. BR 593-21-061

Coating and Chemical Laboratory
Aberdeen Proving Ground
Maryland

UNCLASSIFIED

AUTHOR: Charles B Jordan
CHARLES B. JORDAN, Chemist
Automotive Chemical & Packaging Branch

REVIEWED BY: Virgil O. Hatch
VIRGIL O. HATCH, Chief
Automotive Chemical & Packaging Branch

APPROVED BY: C F Pickett
C. F. PICKETT, Director
Coating & Chemical Laboratory

ABSTRACT

The object of this investigation is to determine the effect of aluminum automotive cooling system components on antifreeze compounds and other cooling system metals.

Bench corrosion tests were used to screen antifreeze compounds and inhibitors for use in systems containing aluminum. Suitable combinations were then placed in simulated vehicle circulation units containing aluminum in conjunction with other metals.

Preliminary results indicate that the presence of aluminum in military automotive cooling systems would present no immediate problem when employing antifreeze meeting Federal Specification O-A-548a with additional inhibitor meeting Federal Specification O-I-490.

I. INTRODUCTION

Aberdeen Proving Ground, Maryland, was directed by OTAC, OMS 5010.11. 8000.01, dated 26 April 1960, Project No. TB5-1, to evaluate coolants and coolant inhibitors with aluminum radiators and aluminum cooling system components.

Many current commercial vehicles are employing aluminum engines and aluminum cooling system components. In the event that vehicles containing aluminum components should enter the military supply system, it was considered advisable to investigate the effect the aluminum would have on specification coolants and inhibitors and on other cooling system metals.

This is an interim report on tests conducted to date.

II. DETAILS OF TEST

A. Bench Corrosion Tests

Bench corrosion tests were conducted in accordance with the procedure outlined in LSD Report No. 205, dated 26 February 1954. This procedure involves the immersion of a set of six metal test specimens (cast iron, aluminum, copper, brass, steel, solder) in a glass flask containing the test solution. The solution is aerated and is refluxed at 180°F for 192 hours, after which the metal test specimens are examined for evidence of corrosion.

B. Simulated Service Circulating Unit Tests

This test involves variations of the test outlined in LSD Report No. 205, dated 26 February 1954. The test apparatus consist of an arrangement of mechanical units in such a manner as to permit the test solution to be circulated in a closed system at a controlled circulation rate and temperature.

In this investigation the unit contained aluminum or cast iron engine blocks and aluminum or brass radiators. The pump was driven by an electric motor. Tests were conducted at a constant coolant temperature of 180°F.

Tared metal test specimens arranged on a metal rod were inserted into the radiator. These specimens were removed and examined at intervals.

C. Test Solutions

Aqueous solutions of Specification O-A-548a Antifreeze were tested with and without additional inhibitor meeting Specification O-I-490. Combinations which appeared most suitable in the bench corrosion test were placed in the simulated service circulating units. Tests are also in progress on a newly developed corrosion inhibitor described in CCL Report No. 113.

III. RESULTS OF TEST

Results of tests are listed in Tables I thru VII of the Appendix. Bench corrosion studies (see Table I) indicated that Specification O-A-548a Antifreeze would perform satisfactorily with aluminum components. Additional O-I-490 inhibitor in the amounts specified in TB-ORD-651 ($\frac{1}{2}$ oz. per quart of make-up

water) improved the overall rating of test specimens. The addition of phosphate further improved the rating.

Results of the test conducted on the all-aluminum circulating unit (see Table II) indicated that no difficulty would be encountered in this type system. After a small initial weight loss, no further attack on the test specimens was evidenced. A hard coating formed on the specimens, which protected the metal from further attack.

The addition of a brass radiator into the aluminum system (see Table III) increased the initial attack on aluminum specimens; however, after initial attack, no further corrosion occurred. There was no attack on brass test specimens.

In the system involving a cast iron block and aluminum radiator, (see Table IV) initial attack on the aluminum test specimens was greater than in the all-aluminum system or the aluminum/brass system. There was no further attack until 2000 hours of operation. At this time there was a sharp increase in weight loss on both the aluminum and cast iron test specimens. The pH value of the test solution showed a substantial drop. Leakage developed at the waterpump shaft. Examination of the interior of the pump showed a large amount of rusty deposits.

The test with the cast iron block and aluminum radiator in which disodium phosphate was added to the test solution (see Table V) showed reduced weight loss of test specimens and great improvement in their appearance. Operation was still good at 2000 hours. Examination of the water pump showed some rust but no heavy deposits such as previously encountered.

The two circulating tests using the newly developed corrosion inhibitor described in CCL Report No. 113, (see Tables VI and VII) were conducted in the aluminum/brass system. Both tests were very satisfactory. pH and reserve alkalinity values were low in each test; however, no excessive corrosion was noted.

IV. DISCUSSION

Tests conducted to date indicate that in the event vehicles containing aluminum radiator and engine components enter the military supply system, no immediate difficulty would be encountered with presently prescribed coolants and inhibitors. However, in some instances, such as illustrated by the test involving a cast iron block and an aluminum radiator, corrosion may be experienced after extended use.

V. PLANNED WORK

It has also been shown by these tests that new inhibitor formulations currently being investigated are applicable to aluminum systems. The double borate/glycol condensate will be tested in the cast iron/aluminum system. Tests are also planned with other additives, such as sodium mercaptobenzothiazole and other phosphates.

An investigation of material meeting Specification MIL-C-11755A, Compound, Antifreeze, Arctic Type, is now in progress. Simulated service tests employing this material will be conducted in the cast iron/aluminum and brass/aluminum systems as well as the all-aluminum system.

VI. RECOMMENDATIONS

It is recommended that this program be continued in order to resolve the best inhibitor combinations for coolants used in military automotive systems including potential aluminum components.

VII. REFERENCES

1. Authority: OMS 5010.11.8000.01, OTAC Project TB5-1, Dated 26 April 1960.

2. Federal Specification, O-A-548a, Antifreeze, Ethylene Glycol, Inhibited, dated 30 December 1958.

3. Federal Specification O-I-490, Inhibitor Corrosion, Liquid Cooling System, dated 27 November 1957.

4. Military Specification MIL-C-11755A, Compound, Antifreeze, Arctic - Type, 17 July 1957.

5. Laboratory Service Division Report No. 205 - Development of a Suitable Laboratory Bench Corrosion Test for Antifreeze Compounds and Inhibitors, dated 26 February 1954.

6. CCL Report No. 113, Improved Multipurpose Corrosion Inhibitor, dated 15 January 1962.

7. Department of the Army Technical Bulletin, TB Ord 651 - Use of Antifreeze Solutions in Engine Cooling Systems in Operating Vehicles, dated 9 Oct. 1959.

APPENDIX

Tables

TABLE I

BENCH CORROSION SCREENING TESTS

Test No.	1	2	3	4	5
Component	50/50 O-A-548a/ water	50/50 O-A-548a/ water	50/50 O-A-548a/ water	100% water	50/50 ethylene glycol/ water
Inhibitor	None	1.2% O-I-490	1.2% O-I-490 0.06% Na_2HPO_4	7.5% multipurpose inhibitor*	7.5% multi-purpose inhibitor*
pH before	7.50	7.58	7.52	8.50	7.20
after	7.48	7.49	7.48	8.40	7.10
RA before	7.0	11.05	11.30	6.20	6.50
after	7.0	11.05	11.30	6.00	6.50
Visual Inspection and wt. change mg/sq cm					
Solder	OK - .35	Slight -.15 stain at contact	OK + .01	OK - .10	Slight -.12 stain
Steel	Slight - .02 stain at contact	Slight - .05 stain at contact	Slight + .01 stain at contact	Slight -.01 stain at contact	Slight .00 stain at contact
Aluminum	Heavy - .40 Stain	Heavy - .78 stain	Heavy - .03 stain	Heavy -.82 stain	OK .00
Cast Iron	Slight - .13 stain at contact	Slight + .02 stain at contact	Slight .00 stain at contact	Slight .00 stain at contact	Slight -.02 stain at contact
Brass	Slight - .01 stain	Slight + .07 stain	Moderate +.01 stain	Slight +.02 stain at contact	Slight -.01 stain at contact
Copper	Slight -.01 stain	Slight + .04 stain	Slight +.01 stain	OK .00	Slight +.02 stain

* Double condensate of borax with propylene glycol and 2-butyne-1,4-diol.

TABLE II

SIMULATED SERVICE TEST - ALL-ALUMINUM SYSTEM

Metal Component - Aluminum block, aluminum radiator

Antifreeze - 50/50 Specification O-A-548a Antifreeze/Water

Inhibitor - O-I-490 Inhibitor added ($\frac{1}{2}$ oz. per quart of water)

Total Hours of Operation - 1268 hours

Test Coupons - Aluminum

RESULTS:

Hours of Operation	0	250	500	750	1000	1250
Coupon No. (Aluminum)		1	2	3	4	5
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		-1.0	-1.0	-0.86	-0.90	-0.80
pH	7.58	--	--	--	--	7.42
RA	11.05	--	--	--	--	10.30

TABLE III

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminumb block, brass and aluminum radiators

Antifreeze - 50/50 Specification O-A-548a Antifreeze/Water

Inhibitor - O-I-490 Inhibitor added ($\frac{1}{2}$ oz. per quart of water)

Total Hours of Operation - 1278 hours

Test Coupons - Brass and Aluminum

RESULTS:

Hours of Operation	0	250	500	750	1000	1250
Coupon No. (Aluminum)		1 A	2 A	3 A	4 A	5 A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		-2.20	-2.00	-2.21	-2.39	-1.90
Coupon No. (Brass)		1 B	2 B	3 B	4 B	5 B
Visual Appearance		OK	OK	Slight stain	Slight stain	Slight stain
Wt. Change mg/sq cm		-0.05	-0.04	0.00	-0.01	-0.02
pH	7.58	--	--	--	--	7.40
RA	11.05	--	--	--	--	10.20

TABLE IV

SIMULATED SERVICE TEST - ALUMINUM/CAST IRON SYSTEM

Metal Component - Cast iron block, aluminum radiator.

Antifreeze - 50/50 Specification O-A-548a Antifreeze/Water.

Inhibitor - O-I-490 Inhibitor added ($\frac{1}{2}$ oz per quart of water) .

Total Hours of Operation - 2272 hrs.

Test Coupons - Cast iron and aluminum.

RESULTS:

Hours of Operation	0	250	750	1250	1750	2250
Coupon No. (Aluminum)		1 A	2 A	3 A	4 A	5 A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		- 2.12	- 2.12	- 2.29	- 2.25	- 3.16
Coupon No. (Cast Iron)		1 C	2 C	3 C	4 C	5 C
Visual Appearance		OK	OK	Slight stain	Slight stain	Moderate stain
Wt. Change mg/sq cm		+ 0.04	.00	- 0.01	+ 0.01	- 0.29
pH	7.58	---	---	---	---	7.10
RA	11.05	---	---	---	---	9.30

Remarks: Water pump contained heavy rust deposits after test.

TABLE V

SIMULATED SERVICE TEST - ALUMINUM/CAST IRON SYSTEM

Metal Component - Cast iron block, aluminum radiator.

Antifreeze - 50/50 Specification O-A-548a Antifreeze/Water.

Inhibitor - O-I-490 Inhibitor ($\frac{1}{2}$ oz per quart of water) and 0.06% Disodium Phosphate added.

Total Hours of Operation - 2013 hours.

Test Coupons - Cast iron and aluminum.

RESULTS:

Hours of Operation	0	500	1000	1500	2000
Coupon No. (Aluminum)		1 A	2 A	3 A	4 A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		- 0.09	- 0.29	- 0.52	- 0.70
Coupon No. (Cast Iron)		1 C	2 C	3 C	4 C
Visual Appearance		OK	OK	Slight stain	Slight stain
Wt. Change mg/sq cm		+ 0.05	+ 0.04	+ 0.06	+ 0.02
pH	7.52	--	--	--	7.12
RA	11.30	--	--	--	8.80

Remarks: Water pump showed some signs of rusting, but no deposits.

TABLE VI

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminum block, brass and aluminum radiators.

Coolant - Water.

Inhibitor - 7½% Double condensate of borax with propylene glycol and 2-butyne-1,4-diol added to water.

Total Hours of Operation - 2038 hours.

Test Coupons - Brass and aluminum.

RESULTS:

Hours of Operation	0	500	1000	1500	2000
Coupon No. (Aluminum)		1 A	2 A	3 A	4 A
Visual Appearance		Heavy stain	Heavy stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		- 4.78	- 3.82	- 4.33	- 4.47
Coupon No. (Cast Iron)		1 B	2 B	3 B	4 B
Visual Appearance		Slight stain	Moderate stain	Heavy stain	Heavy stain
Wt. Change mg/sq cm		- 0.02	- 0.04	- 0.05	- 0.08
pH	8.48	---	---	---	7.22
RA	6.20	---	---	---	2.40

TABLE VII

SIMULATED SERVICE TEST - ALUMINUM/BRASS SYSTEM

Metal Component - Aluminum block, brass and aluminum radiators.

Antifreeze - 50/50 Ethylene glycol/water

Inhibitor - 7½% Double condensate of borax with propylene glycol and 2-butyne-1,4-diol added to antifreeze solution.

Total Hours of Operation - 2006 hours.

Test Coupons - Brass and aluminum.

RESULTS:

Hours of Operation	0	500	1000	1500	2000
Coupon No. (Aluminum)		1 A	2 A	3 A	4 A
Visual Appearance		Slight stain	Moderate stain	Heavy stain	Heavy stain
Wt. Change mg/sqcm		- 0.01	+ 0.04	- 0.02	.00
Coupon No. (Brass)		1 B	2 B	3 B	4 B
Visual Appearance		Slight flash (copper)	Slight flash (copper)	Moderate flash (copper)	Moderate flash (copper)
Wt. Change mg. sq cm		+ 0.04	+ 0.05	+ 0.10	+ 0.40
pH	7.20	--	--	--	6.75
RA	6.50	--	--	--	2.20

DISTRIBUTION LIST FOR OMS CODE NO. 5010.11.8000.01

Department of Defense	No. of Copies
Armed Services Technical Information Agency Arlington Hall Station ATTN: TIPDR Arlington 12, Virginia	10
Department of the Army - Technical Service	
Chief of Ordnance Dept. of the Army ATTN: ORDTB - Fuels & Lubes ORDTB - Materials Washington 25, D. C.	1 1
Aberdeen Proving Ground, Maryland ATTN: Technical Library	2
Commanding Officer Anniston Ord Depot ATTN: ORDKB-QC Laboratory Anniston, Alabama	1
Commanding General Frankford Arsenal ATTN: Pitman-Dunn Laboratory Group Philadelphia, Pa.	1
Commander Detroit Arsenal ATTN: ORDMX-B Center Line, Michigan	1
Commanding General Rock Island Arsenal ATTN: ORDBC-9320 Rock Island, Ill.	1
Commanding General Ordnance Weapons Command ATTN: ORDOW-IX Rock Island, Ill.	1
Commander Watertown Arsenal ATTN: Tech. Group Watertown 72, Mass.	1
Commanding Officer Diamond Ordnance Fuze Laboratories ATTN: Technical Reference Section Washington 25, D. C.	1

	No. of Copies
Commander Ordnance Materials Research Office Watertown Arsenal ATTN: PS&C Division Watertown 72, Mass.	1
Commanding Officer U.S. Army Ord Test Activity Yuma, Arizona	1
Commanding Officer U.S. Army Ord Test Activity ATTN: Automotive Test Division (ORDBG-DP-FY-AU) Yuma, Arizona	1
Commander Ordnance Tank Automotive Command ATTN: ORDMC-REM.3 ORDMC-RRS.3 Detroit Arsenal Center Line, Michigan	2 1
Department of the Army - Other Army Agencies	
Ordnance Office, Headquarters U.S. Army Caribbean, Corozal Fort Clayton, Canal Zone	1
Other Government Agencies	
Office of Technical Services Acquisitions Section Department of Commerce Washington 25, D. C.	200
Foreign Address	
Ministry of Supply Staff British Joint Services Mission 1800 K Street, N. W. Washington 6, D. C.	2
Canadian Army Staff ATTN: GSO-1, A&R Section 2450 Massachusetts Avenue, N. W. Washington 8, D. C.	2

AD No_____ Accession No_____ Coating & Chemical Laboratory, Aberdeen Proving Ground, Md., CCL # 125 - COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS - FIRST REPORT - Charles B. Jordan Rpt No. 125, 21 June 1962, 16 pgs, OMS 5010.11.8000.01, DA Proj No BR 593-21-061 The object of this investigation is to determine the effect of aluminum automotive cooling system components on antifreeze compounds and other cooling system metals. Bench corrosion tests were used to screen antifreeze compounds and inhibitors for use in systems containing aluminum.	Unclassified	AD No_____ Accession No_____ Coating & Chemical Laboratory, Aberdeen Proving Ground, Md., CCL # 125 - COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS - FIRST REPORT - Charles B. Jordan Rpt No. 125, 21 June 1962, 16 pgs, OMS 5010.11.8000.01, DA Proj No BR 593-21-061 The object of this investigation is to determine the effect of aluminum automotive cooling system components on antifreeze compounds and other cooling system metals. Bench corrosion tests were used to screen antifreeze compounds and inhibitors for use in systems containing aluminum.	Unclassified
AD No_____ Accession No_____ Coating & Chemical Laboratory, Aberdeen Proving Ground, Md., CCL # 125 - COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS - FIRST REPORT - Charles B. Jordan Rpt. No. 125, 21 June 1962, 16 pgs, OMS 5010.11.8000.01, DA Proj No BR 593-21-061 The object of this investigation is to determine the effect of aluminum automotive cooling system components on antifreeze compounds and other cooling system metals. Bench corrosion tests were used to screen antifreeze compounds and inhibitors for use in systems containing aluminum.	Unclassified	AD No_____ Accession No_____ Coating & Chemical Laboratory, Aberdeen Proving Ground, Md., CCL # 125 - COMPATIBILITY OF COOLANTS WITH AUTOMOTIVE COOLING SYSTEMS CONTAINING ALUMINUM COMPONENTS - FIRST REPORT - Charles B. Jordan Rpt No. 125, 21 June 1962, 16 pgs, OMS 5010.11.8000.01, DA Proj No BR 593-21-061 The object of this investigation is to determine the effect of aluminum automotive cooling system components on antifreeze compounds and other cooling system metals. Bench corrosion tests were used to screen antifreeze compounds and inhibitors for use in systems containing aluminum.	Unclassified

Unclassified

Suitable combinations were then placed in simulated vehicle circulation units containing aluminum in conjunction with other metals.

Preliminary results indicate that the presence of aluminum in military automotive cooling systems would present no immediate problem when employing antifreeze meeting Federal Specification O-A-548a with additional inhibitor meeting Federal Specification O-I-490.

Unclassified

Suitable combinations were then placed in simulated vehicle circulation units containing aluminum in conjunction with other metals.

Preliminary results indicate that the presence of aluminum in military automotive cooling systems would present no immediate problem when employing antifreeze meeting Federal Specification O-A-548a with additional inhibitor meeting Federal Specification O-I-490.

Unclassified

Suitable combinations were then placed in simulated vehicle circulation units containing aluminum in conjunction with other metals.

Preliminary results indicate that the presence of aluminum in military automotive cooling systems would present no immediate problem when employing antifreeze meeting Federal Specification O-A-548a with additional inhibitor meeting Federal Specification O-I-490.

Unclassified

Suitable combinations were then placed in simulated vehicle circulation units containing aluminum in conjunction with other metals.

Preliminary results indicate that the presence of aluminum in military automotive cooling systems would present no immediate problem when empolying antifreeze meeting Federal Specification O-A-548a with additional inhibitor meeting Federal Specification O-I-490.